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PRELIMINARY AIRWORTHINESS EVALUATION, AH-1G WITH THE AIRBORNE T--ETC(U)
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U.S. ARMY
AVRADCOM

LEVEL II

PRELIMINARY AIRWORTHINESS EVALUATION

AH-1G WITH THE AIRBORNE TARGET AQUISITION FIRE CONTROL SYSTEM AND THE HELLFIRE MODULAR MISSILE SYSTEM INSTALLED

FINAL REP[redacted]RT. Jun 78-Jan 79

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAAEFA PROJECT NO. 78-02	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PRELIMINARY AIRWORTHINESS EVALUATION AH-1G W/ AIRBORNE TARGET AQUISITION FIRE CONTROL SYSTEM & HELLFIRE MODULAR MISSILE SYSTEM INSTALLED		5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT June 1978 - January 1979 6. PERFORMING ORG. REPORT NUMBER Project No. 78-02
7. AUTHOR(s) MAJ PATRICK J. MOE RAYMOND B. SMITH		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY EDWARDS AIR FORCE BASE, CALIFORNIA 93523		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS A1-9-EP236-08-EC-01
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY EDWARDS AIR FORCE BASE, CALIFORNIA 93523		12. REPORT DATE JULY 1979 13. NUMBER OF PAGES 35
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

ATAFCS
Hellfire (HMMS)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The AH-1G helicopter with the HELLFIRE Modular Missile System (HMMS) and the Airborne Target Acquisition Fire Control System (ATAFCS) is being used as a surrogate trainer for the YAH-64 helicopter. The United States Army Aviation Engineering Flight Activity was tasked to provide quantitative and qualitative data on the handling qualities of the helicopter, obtain limited level flight performance data, and obtain limited handling qualities of the helicopter with only the ATAFCS installed. — 3 next page

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20. Abstract

cont.

The test helicopter was a production AH-1G helicopter (212 tail rotor) modified with an ATAFCS mockup and carrying eight HELLFIRE missiles. Six productive flight test hours were flown in six flights. No shortcomings or deficiencies attributable to HMMS and ATAFCS installation were found. The AH-1G helicopter, with HMMS and ATAFCS installed, exhibits an additional equivalent flat plate area of 4.0 ft^2 compared to the standard AH-1Q helicopter. The handling qualities of the helicopter with only the ATAFCS installed are essentially the same as the production AH-1G helicopter.

DEPARTMENT OF THE ARMY
HQ, US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
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DRDAV-D

4 OCT 1979

SUBJECT: Preliminary Airworthiness Evaluation, AH-1G with the Airborne Target Acquisition Fire Control System and HELLFIRE Modular Missile System Installed, AEFA Project Number 78-02

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Development and Qualification position on the subject report. This report covers an evaluation of an AH-1G configured with the subject systems installed to insure the airworthiness of the helicopter for use as a test bed for the HELLFIRE Modular Missile System (HMMS) and as a surrogate trainer for YAH-64 pilot training. Consequently, no attempt to conduct full airworthiness qualification was attempted in the interest of cost effectiveness and in providing a flight envelope sufficient to meet operational requirements. An Airworthiness Release per AR 70-62 has been issued to the operational units with appropriate flight envelope restrictions.

2. This Directorate agrees with the conclusions in paragraph 8 of the report. However, the drag characteristics of the AH-1G with the HMMS and Airborne Target Acquisition Fire Control System (ATAFCS) were only compared against the AH-1Q. This resulted in an equivalent increased drag area of 4.0 ft^2. An additional 2.5 ft^2 of equivalent drag area is evident for a total of 6.5 ft^2 when the AH-1G with the HMMS/ATAFCS installed is compared against the clean configuration AH-1G. In general, the increased drag results in a 10 percent reduction in best range speed, maximum airspeed and range as compared to the clean configuration AH-1G. The operational user has been advised to use data for the "Heavy Hog" configuration in TM 55-1520-221-10, Operator's Manual Army Model AH-1G, with change 6, 16 January 1976, for determining performance of the AH-1G with the HMMS/ATAFCS installed. When operator manuals for the AH-1G, which present delta drag data, become available, a delta drag of 6.5 ft^2 above the clean configuration should be assumed for this system. The operational user has also been advised that the airspeed position error with the HMMS/ATAFCS installed is slightly (up to 3 kts) different than that of the standard AH-1G.

FOR THE COMMANDER:

Charles C. Crawford

CHARLES C. CRAWFORD, JR.
Acting Director of Development
and Qualification

AH-1G with ATAFCS and Hellfire Installed

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INTRODUCTION

BACKGROUND

1. The Hellfire Modular Missile System (HMMS) is being developed by the United States Army Missile Research and Development Command (MIRADCOM) as the primary weapons system for the YAH-64 advanced attack helicopter. The non-availability of a YAH-64 helicopter required that initial Hellfire missile engineering design tests (EDT) be conducted using the AH-1G helicopter as a flight test vehicle. The test helicopter was configured with the HMMS and a mock-up of the Airborne Target Acquisition Fire Control System (ATAFCS). The test helicopter will be used as a surrogate trainer for the YAH-64 pilot training and Hellfire operational test (OT) II. In June 1978, the United States Army Aviation Engineering Flight Activity (USAAEFA) was tasked by the United States Army Aviation Research and Development Command (AVRADCOM) to conduct a Preliminary Airworthiness Evaluation (PAE) of an AH-1G helicopter modified with aerodynamically similar replicas of ATAFCS and HMMS (ref 1, app A). A test plan was prepared in August 1978 (ref 2) and an airworthiness release was issued in January 1979 (ref 3).

TEST OBJECTIVES

2. The objectives of the preliminary airworthiness evaluation of the AH-1G helicopter with the HMMS and ATAFCS installed were as follows:

a. Provide quantitative and qualitative handling qualities data to verify the contractors flight envelope developed during EDT flight tests.

b. Obtain limited level flight performance data.

c. Obtain limited handling qualities data (ATAFCS configuration only).

DESCRIPTION

3. The test aircraft (SN 70-16069) was originally a production AH-1G helicopter with a 212 tail rotor. Changes made to the test helicopter from production configuration included:

a. Removal of the aircraft nose section at fuselage station (FS) 46 and installation of a nonfunctioning model of the ATAFCS turret assembly.

b. Nonfunctioning ATAFCS cockpit control panels were installed in both cockpits.

c. Addition of 129 pounds of lead ballast in the ammunition bay (FS 100) to simulate the weight of additional ATAFCS equipment.

d. Addition of 50 pounds of lead ballast in the tail stinger area (FS 477).

e. Replacement of the AH-1G outboard wing pylons with AH-1S pylons.

f. Relocation of the airspeed pitot tube from the nose area to the left side of the forward pylon fairing (similar to the AH-1S).

g. Attachment of Hellfire launchers with four dummy missiles to the outboard pylons (for a portion of the test program).

h. Installation of a test instrumentation package in the ammunition bay with operating controls located in both cockpits. A detailed description of the AH-1G helicopter is contained in reference 5, appendix A. Detailed descriptions of both the HMMS and the ATAFCS are contained in appendix B.

TEST SCOPE

4. The preliminary airworthiness evaluation was conducted at Edwards Air Force Base, California (elevation 2302 feet) from 18 January 1979 through 23 January 1979. During the evaluation, 6 flights were conducted for a total of 9 hours, of which 6 hours were productive. Flight testing was conducted in two configurations which were: (1) ATAFCS only (ATAFCS model installed with no wing stores), and (2) ATAFCS/8-Hellfire (ATAFCS model installed with 8 Hellfire missiles mounted, 4 on each outboard wing store location). The helicopter handling qualities were evaluated against the requirements of Military Specifications, MIL-H-8501A (ref 4, app A). Aircraft instrumentation installation and instrumentation maintenance were accomplished by contractor personnel. Data reduction and analysis were accomplished by USAAEFA. All flight tests were conducted at a forward longitudinal center of gravity, 8800 pounds average gross weight, and with a trim main rotor speed of 324 rpm. Airspeeds ranged from zero to 130 knots calibrated airspeed (KCAS) with altitude varying from 1700 ft ground level density altitude (H_D) to 5000 ft H_D. Flight restrictions and operating limitations presented in the AH-1G Operator's Manual (ref 5) as modified by an Airworthiness Release (ref 3) were observed throughout the evaluation.

TEST METHODOLOGY

5. The aircraft was tested in accordance with the test procedures outlined in the US Navy Test Pilot School Flight Test Manual, Helicopter Performance and Helicopter Stability and Control (refs 6 and 7, app A). Data analysis methods are described in appendix D. A detailed listing of the test instrumentation is contained in appendix B. Comparisons were made to previous AH-1 reports which most closely matched configurations of test aircraft.

RESULTS AND DISCUSSION

GENERAL

6. The contractors flight envelope was verified during flight testing of the AH-1G helicopter with the HMMS and ATAFCS installed. One level performance test was conducted at an average thrust coefficient (C_T) of 0.004914. A comparison of the results of this test with the data from AH-1Q helicopter (ref 8, app A) indicate an approximate additional equivalent flat plate area of 4.0 ft. The handling qualities of the AH-1G with the HMMS and ATAFCS installed, as well as the helicopter configured with only the ATAFCS, were essentially the same as previous AH-1 helicopters. The conditions of test are shown in table 1.

Level Flight Performance

7. One level flight performance test was conducted at the conditions shown in table 1. Data were obtained in stabilized, ball-centered level flight at a constant ratio of gross weight to density ratio (w/σ). The results are presented in figure 1, appendix E.

8. Data from USAAEFA Project No. 72-43 (ref 8, app A) were used as a comparison in order to estimate additional drag due to the installation of the ATAFCS and HMMS. Figure 1 shows fairings for the AH-1Q helicopter in the clean, 4-TOW, and 8-TOW configurations as well as the data for the AH-1G helicopter with the ATAFCS and HMMS installed. As compared to the AH-1Q helicopter in the clean configuration, the test helicopter had approximately 4.0 feet^2 of additional equivalent flat plate area.

HANDLING QUALITIES

Control Positions in Trimmed Forward Flight

9. Control positions in trimmed forward flight were determined in ball-centered, trimmed level flight at the conditions shown in table 1. Data were recorded at airspeeds from 44 KCAS to 125 KCAS. Test results are shown in figure 2, appendix E. The helicopter requires forward cyclic movement with increasing airspeed. The data are representative of previous AH-1G helicopter test results. The control positions in trimmed forward flight are satisfactory.

Static Longitudinal Stability

10. Static longitudinal stability was evaluated at the conditions listed in table 1. For each test condition, the aircraft was trimmed in steady-heading, ball-centered, level flight. With the collective control held fixed, the aircraft was stabilized at incremental airspeeds greater and less than the trim speed. Data were recorded at each stabilized airspeed. Test results are presented in figures 3 and 4, appendix E. The collective fixed static longitudinal stability was positive (forward cyclic with increasing airspeed) at all conditions listed with similar position and force gradients as the standard AH-1G with 212 tail rotor.

Table 1. Test Conditions

Test[1]	Density Altitude (ft)	Airspeed (KCAS)[2]	Center of Gravity (fs.)	Configuration[3]
Level flight performance	5000	50 to 130	194.3	ATAFCS/8-Hellfire
Trim control positions	5000	44 to 125	194.2	ATAFCS/8-Hellfire
Static longitudinal stability	5000	63, 116	194.3	ATAFCS/8-Hellfire
Lateral-directional stability	5000	63, 120	194.3	ATAFCS/8-Hellfire
Dynamic stability[4]	5000	60, 100, 120	194.2	ATAFCS/8-Hellfire
Maneuvering stability	5000	61, 117	194.2	ATAFCS/8-Hellfire
Controllability	1800	zero	193.5	ATAFCS only
Low-speed flight	1700	zero to 30[5]	193.5	ATAFCS only
Simulated sudden[6] engine failure	5000	44 to 118	193.5	ATAFCS only

[1] 324 Main rotor rpm, 8800 lbs. average gross weight, SCAS ON except where noted.
[2] Knots calibrated airspeed.
[3] ATAFCS/8-Hellfire: ATAFCS installed, launcher with 4 missiles both outboard stations; ATAFCS only: ATAFCS installed only.
[4] SCAS ON (60, 120 KCAS); SCAS OFF (60, 100 KCAS).
[5] Knots true airspeed (KTAS); forward, rearward and sideward flight.
[6] 324 to 280 Main rotor rpm.

Static Lateral Directional Stability

11. The static lateral directional stability of the helicopter was evaluated at the conditions shown in table 1. The test was performed by first trimming the aircraft in level flight, with the ball centered. The collective was then held fixed and a sideslip was induced with cyclic and directional pedals. Since the helicopter had no test instrumentation to indicate sideslip, approximate sideslip angles were achieved by maintaining a constant ground track while varying the heading using the radio magnetic indicator (RMI). Test results are shown in figures 5 and 6, appendix E.

12. The static directional stability, as indicated by the variation of directional control position with sideslip, was positive (increasing right directional control displacement with increasing left sideslip). Directional stability increased with airspeed. Dihedral effect, as indicated by the variation of lateral control with sideslip, was also positive (increasing right lateral control displacement with increasing right sideslip), and was essentially linear at all points tested. Sideforce characteristics, as indicated by the variation of roll attitude with sideslip, were positive for all test conditions (increasing roll attitude in the direction of sideslip with increasing sideslip). The static lateral-directional stability of the aircraft is essentially the same as for the standard production AH-1G with the 212 tailrotor (ref 9, app A).

Maneuvering Stability

13. The maneuvering stability was evaluated at the conditions shown in table 1. The test was performed by trimming the helicopter in level, ball-centered flight, fixing the collective and incrementally varying the load factor (g) by banking the helicopter left and right while maintaining constant airspeed. Altitude was allowed to decrease and data were recorded at each stabilized point. Test results are shown in *appendix E, figures 7 and 8.*

14. The maneuvering stability (stick-fixed), as indicated by a variation of longitudinal control position with load factor, was positive (increasing aft cyclic with increasing load factors) at all conditions tested. At 61 KCAS, the control position gradient was approximately 3.5 inches/g while at 117 KCAS, the gradient was 2.5 inches/g. The maneuvering stability of the helicopter compared favorably to previous AH-1G helicopters.

Dynamic Stability

15. Dynamic stability was evaluated SCAS ON and OFF at the conditions shown in table 1. The purpose of the tests was to determine the characteristics of the aircraft through analysis of the longitudinal and lateral-directional responses long period motion, and the spiral stability.

16. The short period was evaluated by stabliizing the aircraft in ball-centered, level flight and pulsing the aircraft controls. A control pulse of approximately 1-inch displacement was held for 0.5 seconds and the control then returned to trim. Pulses were accomplished in each axis and the resulting aircraft reactions were recorded. SCAS ON the aircraft reaction was essentially deadbeat in the longitudinal and lateral axis at the two airspeeds tested (60, 120 KCAS). The oscillations in the directional axis were convergent with generally three oscillations to a fully damped condition. SCAS OFF the longitudinal short period was deadbeat. The lateral-directional was lightly damped (.13) with a period of approximately 4 seconds at both airspeeds tested with the damping decreasing with increasing airspeed. The characteristics were unchanged from the standard AH-1G helicopter.

17. The long period motion was evaluated both SCAS ON and OFF. At 60 KCAS (SCAS ON) the long period was neutrally damped, with a period of 47 seconds. With the SCAS OFF, the long period was convergent with a period of approximately 30 seconds at both airspeeds tested (60, 100 KCAS). The long period motion of the AH-1G with HMMS and ATAFCS installed is similar to previous AH-1G helicopters.

18. Spiral stability was evaluated at the conditions noted in table 1. The aircraft was trimmed in level, ball-centered flight. A 10° bank was introduced using only directional controls Controls were then returned to trim and the resulting helicopter motions recorded. Spiral stability (the tendency to return to a level attitude) was found to be neutral when the aircraft was banked to the right and slightly divergent when banked to the left. The time to double amplitude in the divergent mode was in excess of 30 seconds. The dynamic stability of the helicopter was unchanged from the basic AH-1G.

Controllability

19. Controllability was evaluated in the clean configuration at the conditions shown in table 1. The aircraft was stabilized at a hover approximately 100 feet above ground level and step inputs of varying magnitude were introduced in the control system using the longitudinal, lateral, or direction control. The controls were held fixed for 3 seconds or until recovery was required. Results are shown in figures 9, 10, and 11, appendix E. The hover controllability of the helicopter is unchanged from the AH-1G.

Low-Speed Flight Characteristics

20. Low speed flight tests were conducted in winds of less than three knots at the conditions shown in table 1. A pace car equipped with a calibrated radar speed gun was used as a speed reference. The aircraft was flown from zero to 30 KTAS in 5-knot increments at a skid height of approximately 10 feet and data were recorded at each stabilized point. Test results are shown in figures 12 and 13, appendix E, and are similar to previous AH-1G helicopter flight tests.

AIRCRAFT SYSTEMS FAILURES

Simulated Engine Failures

21. The helicopter reaction to sudden engine failures was evaluated at the conditions shown in table 1. The helicopter was trimmed in level, ball-centered flight and the throttle was rapidly reduced to idle while all the controls were held fixed for two seconds or until recovery was necessary. Data were recorded throughout the maneuver, and are presented in table 2. The collective delay time (time from throttle chop until the collective control was lowered) for the level flight conditions tested met or exceeded the two-second limit imposed by MIL-H-8501A. The first indication of engine failure was an abrupt yaw to the left and the sound of decreasing engine speed. The sudden engine failure characteristics of the AH-1G with HMMS and ATAFCS are unchanged from the AH-1G.

Table 2. Simulated Engine Failures[1]

Trim A/S (KCAS)	Entry Altitude (ft)	Torque (psi)	Gross Weight (lb)	Max Left Yaw Rate (deg/sec)	Max Left Roll Rate (deg/sec)	Max RPM Change rpm	Delay Time (sec)
38	5700	23	8500	13 lt	2 lt	50	2.7
59	5550	22	8400	14 lt	3 lt	48	2.7
80	5600	28	8400	17 lt	3 lt	50	2.0
104	5600	28	8400	17 lt	3 lt	48	2.0
117	5500	33	8400	18 lt	5 lt	52	2.0
118	5550	33	8300	23 lt	6 lt	56	2.0

[1] Rotor speed: 324 at trim point
OAT ~ 0 °C.
All runs trimmed to level flight.

CONCLUSIONS

General

22. The handling qualities of the AH-1G with the ATAFCS and HMMS installed, and with only the ATAFCS installed, are unchanged from previous AH-1 helicopters.

Specific

23. The addition of the ATAFCS and HMMS installation to the AH-1G produced approximately 4.0 ft^2 of additional equivalent flat plate area compared to the AH-1Q helicopter in the clean configuration.

24. No deficiencies or shortcomings attributable to the ATAFCS and HMMS were found.

APPENDIX A. REFERENCES

1. Letter, AVRADCOM, DRDAV-EQ, 13 November 1978, AVRADCOM/AEFA Test Request No. 78-02, subject: Preliminary Airworthiness Evaluation of AH-1G Helicopter with HMMS and ATAFCS Installation.

2. Test Plan, USAAEFA, Project No. 78-02, *Army Preliminary Airworthiness Evaluation of an AH-1G Helicopter with the Hellfire Modular Missile System and the Airborne Target Acquisition Fire Control System Installed,* August 1978, unpublished.

3. Letter, AVRADCOM, DRDAV-EQ, 10 January 1979, subject: Airworthiness Release for USAAEFA to Conduct USAAVRADCOM/USAAEFA Project No. 78-02.

4. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements For,* 7 September 1961, with Amendment 1, 3 April 1962.

5. Technical Manual, TM 55-1520-221-10, *Operator's Manual, Army Model AH-1G Helicopter,* 19 June 1971, with changes 1 through 6.

6. Flight Test Manual, Naval Air Test Center, FTM No. 101, *Stability and Control,* 10 June 1968.

7. Flight Test Manual, Naval Air Test Center, FTM No. 102, *Performance,* 28 June 1968.

8. Final Report, USAASTA, Project 72-43, *Airworthiness and Flight Characteristics Evaluation AH-1Q Helicopter,* July 1973.

9. Final Report, USAASTA, Project 72-30, *Engineering Flight Test AH-1G Helicopter with Model 212 Tail Rotor Part II Performance and Handling Qualities,* September 1973.

APPENDIX B. DESCRIPTION

TEST HELICOPTER

1. The test helicopter, SN 76-16069, an AH-1G attack helicopter with 212 tail rotor, was manufactured by Bell Helicopter Textron, Fort Worth, Texas, and was modified by Missile Systems Division, Rockwell International, Columbus, Ohio. Modifications to the helicopter included replacement of the AH-1G outboard pylons with AH-1S pylons; removal of the nose of the aircraft to FS 46 and replacement with a dummy ATAFCS turret assembly relocation of the pitot tube to the left side of the forward pylon fairing (similar to AH-1S), and the addition of a 50-pound stinger weight at FS 477. The ATAFCS electronic and aircraft instrumentation packages were located in the ammunition bay.

HMMS LAUNCHER

2. The Hellfire launcher (fig. 1) is a modular 4-rail/2-rail design compatible with the AH-1 and YAH-64 helicopter. The launcher incorporates the standard 14-inch lug spacing and is made up of the launcher structure, the electronic command signal programmer (ECSP) and the stored gas distribution system (SGDS) (fig. 1). The launcher structure consists of three major subassemblies; the hardback, the lower rail supports, and the rails. The hardback incorporates the lugs for the standard 14-inch stores rack and is a hollow casting that accepts the ECSP in the forward end and the SGDS in the aft end. The two lower rail supports are bolted to the bottom of the hardback. The missiles were dummy replicas of laser and IR Hellfire missiles.

AIRBORNE TARGET ACQUISITION FIRE CONTROL SYSTEM

3. The ATAFCS is a fire control system designed for the YAH-64 advanced attack helicopter (figs. 2 and 3). The system consists of the ATAFCS turret, electonics, and operator controls. On the test aircraft the ATAFCS system was replaced by a model turret of the exact size, shape, and weight. Ballast in the ammo bay simulated additional items used in the system. Nonfunctioning cockpit controls were provided to both cockpits. Major airframe modifications included removal of the nose and battery compartment at FS 46. This station was reinforced to accept the turret mounting.

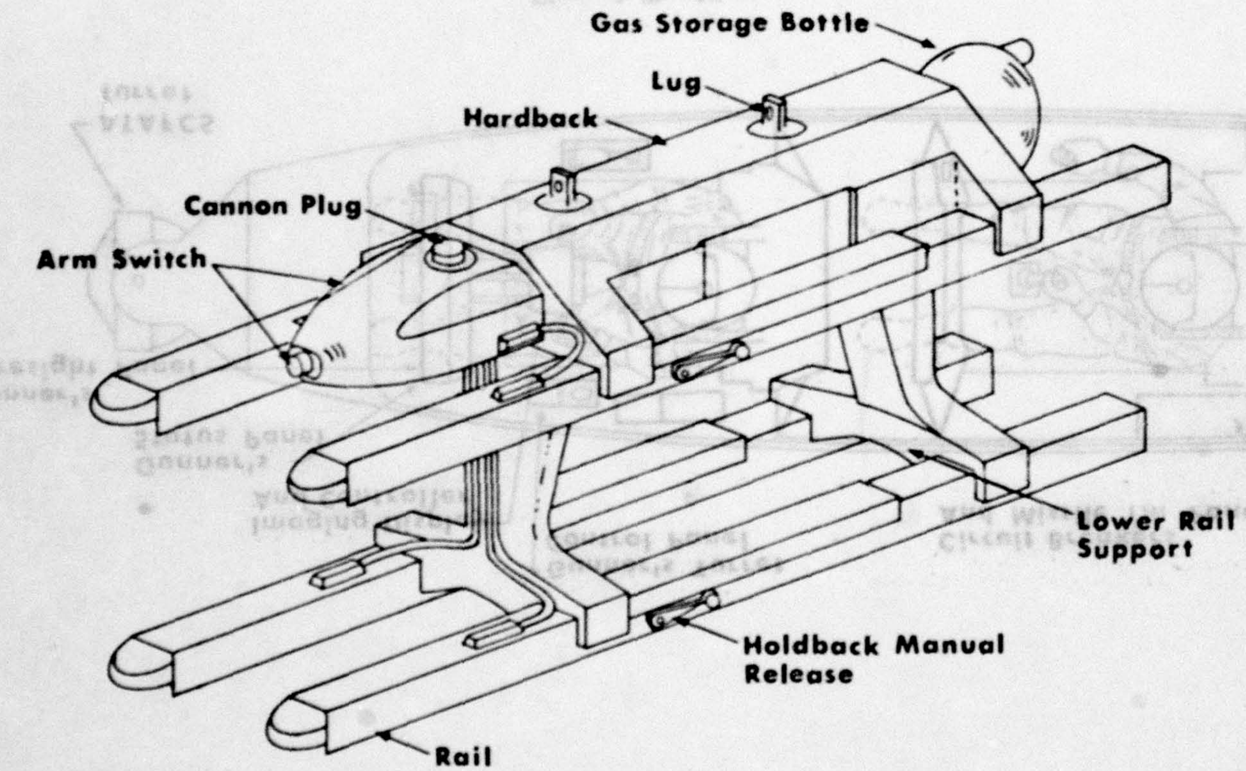


Figure 1. Hellfire Launcher

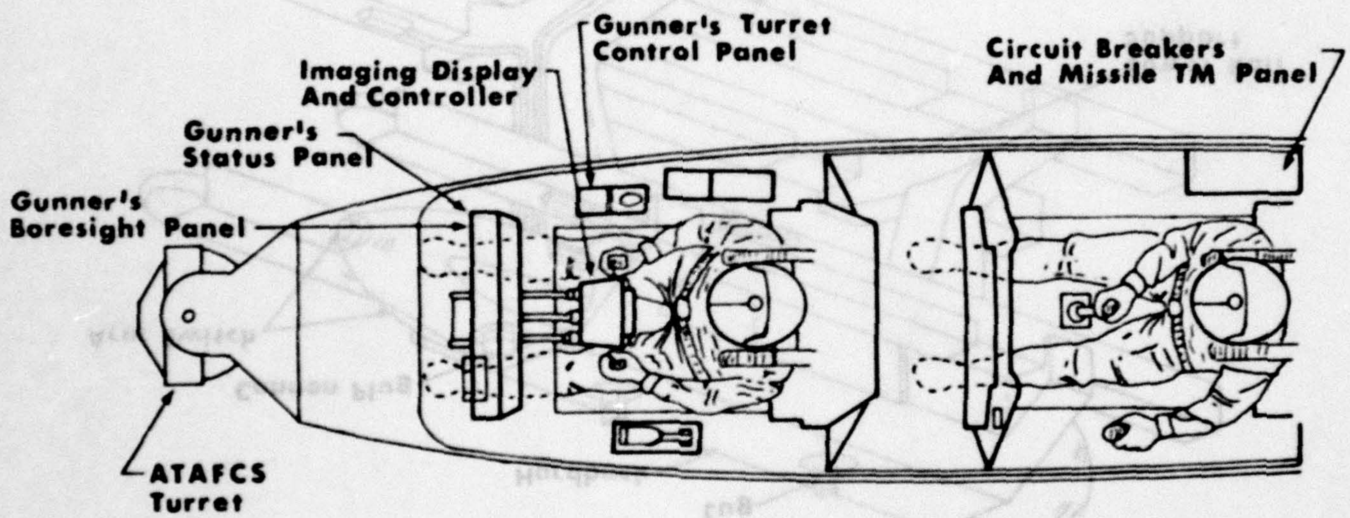


Figure 2. Plan View

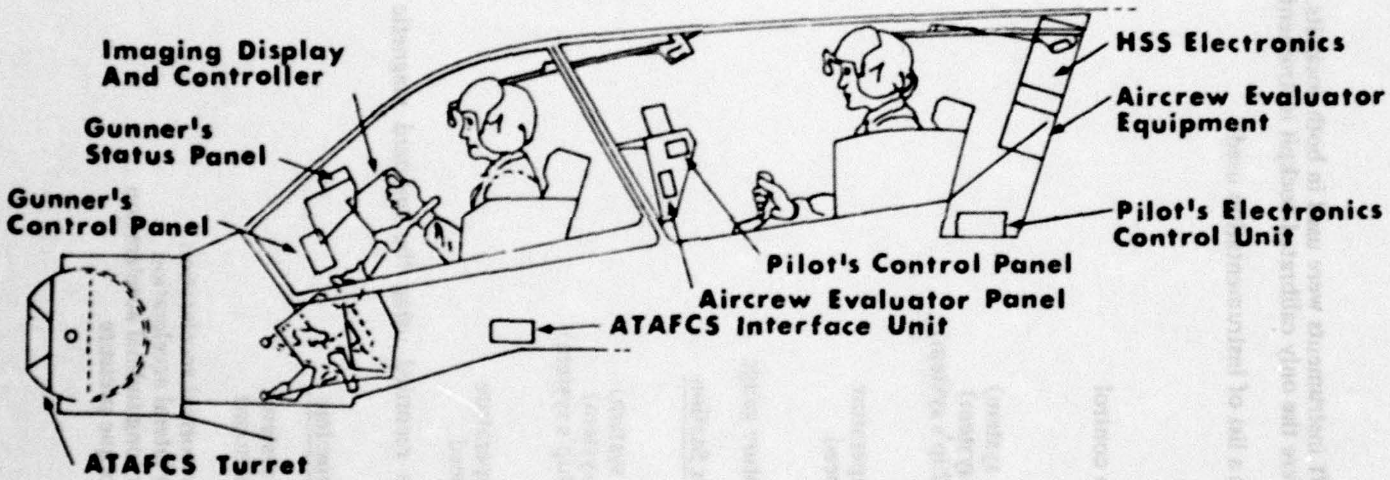


Figure 3. Side View

APPENDIX C. INSTRUMENTATION

1. Standard aircraft instruments were used in both cockpits. The pilot and copilot airspeed indicators were the only calibrated cockpit instruments.

2. The following is a list of instrumentation used.

<u>Pilot Station</u>

Event switch
Instrumentation control

<u>Pilot Panel</u>

Airspeed (ship's system)
Altitude (ship's system)
Rate of climb (ship's system)
Rotor speed
Engine torque
Exhaust gas temperature
Gas generator speed
Attitude gyro
Fuel gauge
Free air temperature gauge

<u>Copilot/Engineer Station</u>

Control fixtures
Airspeed (ship's system)
Altitude (ship's system)
Rate of climb (ship's system)
Rotor speed
Engine torque
Exhaust has temperature
Gas generator speed

3. Data parameters recorded using the onboard magnetic tape system include the following:

<u>Digital PCM Parameters</u>

Airspeed (ship's system)
Altitude (ship's system)
Main rotor rpm
Center-of-gravity normal acceleration
Center-of-gravity lateral acceleration
Center-of-gravity longitudinal acceleration
Engine output torque pressure
Pilot event

Control positions:

- Longitudinal cyclic
- Lateral cyclic
- Collective
- Directional
- Throttle

Attitude:

- Pitch
- Roll
- Yaw

Angular velocity:

- Pitch
- Roll
- Yaw

Battery voltage

Voice

APPENDIX D. DATA ANALYSIS METHODS

GENERAL

1. Data for use in determining handling qualities characteristics of the test aircraft were collected using standard test methods as described in reference 7, appendix A.

LEVEL FLIGHT PERFORMANCE

2. Level flight performance was determined at one specific condition ($C_T = 49.14 \times 10^{-4}$). The test data were corrected to the average test day conditions and were then compared to baseline data obtained from USAASTA (US Army Aviation Systems Test Activity) Report No. 72-43 (ref 8, app A). The following nondimensional coefficients were used to generalize the level flight performance test results:

Coefficient of power (C_P).

$$C_P = \frac{SHP \times 550}{\rho A(\Omega R)^3} \tag{1}$$

Coefficient of thrust (C_T).

$$C_T = \frac{W}{\rho A(\Omega R)^2} \tag{2}$$

Advance ratio (μ).

$$\mu = \frac{V_T}{\Omega R} \tag{3}$$

Where:

SHP = Engine output shaft horsepower.

ρ = Air density (lb - sec^2/ft^4).

A = Main rotor disc area (ft^2).

Ω = Main rotor angular velocity (rad/sec).

R = Main rotor radius (ft).

W = Aircraft gross weight (lb).

V_T = True airspeed (ft/sec).

Changes in the equivalent flat plate area (f_e) for various aircraft configurations were calculated by the following equation:

DYNAMIC RESPONSE

3. The dynamic response characteristics of the aircraft were evaluated to determine the damping ratios (ζ); Damping ratios were determined for all conditions tested using the logarithmic decrement method. The logarithmic decrement is defined as the natural logarithm of the ratio of any two successive peaks (fig. 1).

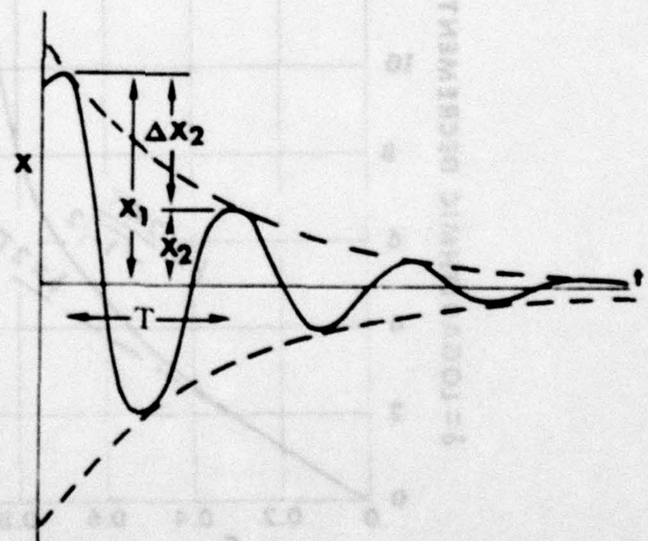


Figure 1. Rate of Decay of Oscillation Measured by the Logarithmic Decrement

The logarithmic decrement δ is mathematically expressed as:

$$\delta = \ln \frac{x1}{x2} = \ln \frac{e^{-\zeta \omega n T_1}}{e^{-\zeta \omega n\,(T+\tau)}} = \ln e^{\zeta \delta_n \tau} = \zeta \delta_n \tau \qquad (4)$$

Since the period of the damped oscillation is equal to:

$$\tau = 2\pi/\omega_n \sqrt{1-\zeta^2} \qquad (5)$$

The decrement can be rewritten as:

$$\delta = \ln \frac{x1}{x2} = 2\pi\zeta^2/\sqrt{1-\zeta^2} \qquad (6)$$

As seen in figure 2 for small values of ζ:

$$\delta<3,\ \zeta = \ln \frac{x1}{x2} \;/2\pi(\zeta<0.3) \qquad (7)$$

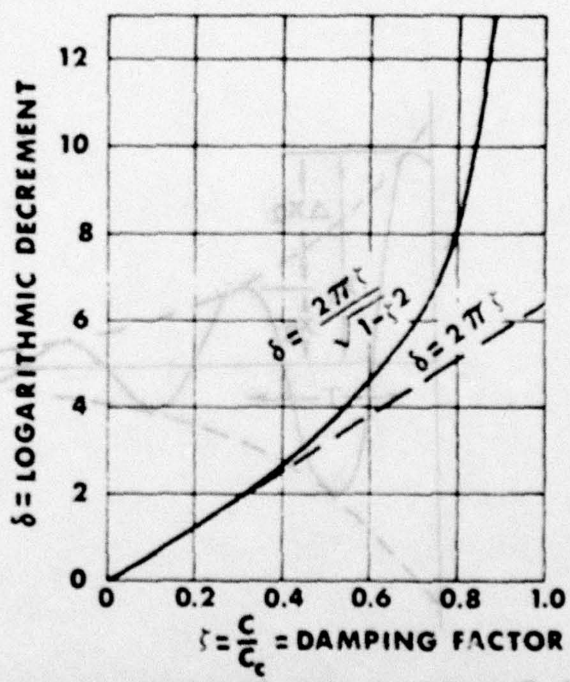


Figure 2. Logarthmic Decrement as function of δ

The frequency is defined as $\omega = 2\pi/\tau$ rad/sec; the natural frequency is defined as:

$$\omega_n = 2\pi/\tau\sqrt{1-\zeta^2} \tag{8}$$

AIRSPEED CALIBRATION

4. An airspeed calibration was performed using the trailing bomb method. Results are shown in figure 3.

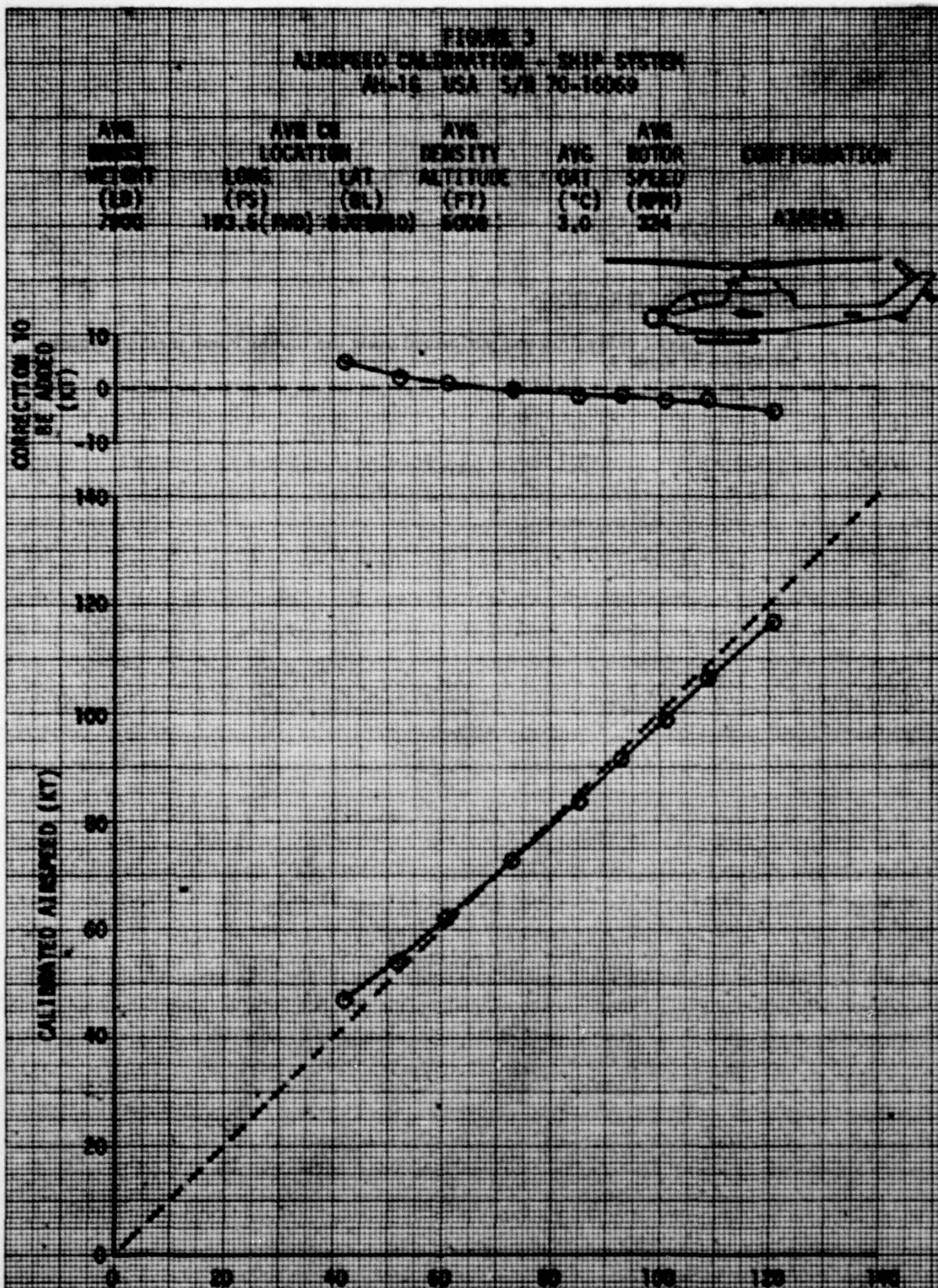


FIGURE 3
AIRSPEED CALIBRATION - SHIP SYSTEM
AH-1G USA S/N 70-16069
AVG
AVG CG LOCATION
AVG DENSITY ALTITUDE (FT)
AVG OAT (°C)
AVG ROTOR SPEED
CONFIGURATION
LONG (FS)
LAT (BL)
5000
3.0
324
CORRECTION TO BE ADDED (KT)
10
0
-10
CALIBRATED AIRSPEED (KT)
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
INDICATED AIRSPEED (KT)

APPENDIX E. TEST DATA

INDEX

FIGURE 1
LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
8740	194.3(FWD)	0.0(MID)	4180	5.0	324	0.004914	ATAFCS/8-HELLFIRE

NOTE: SCAS ON

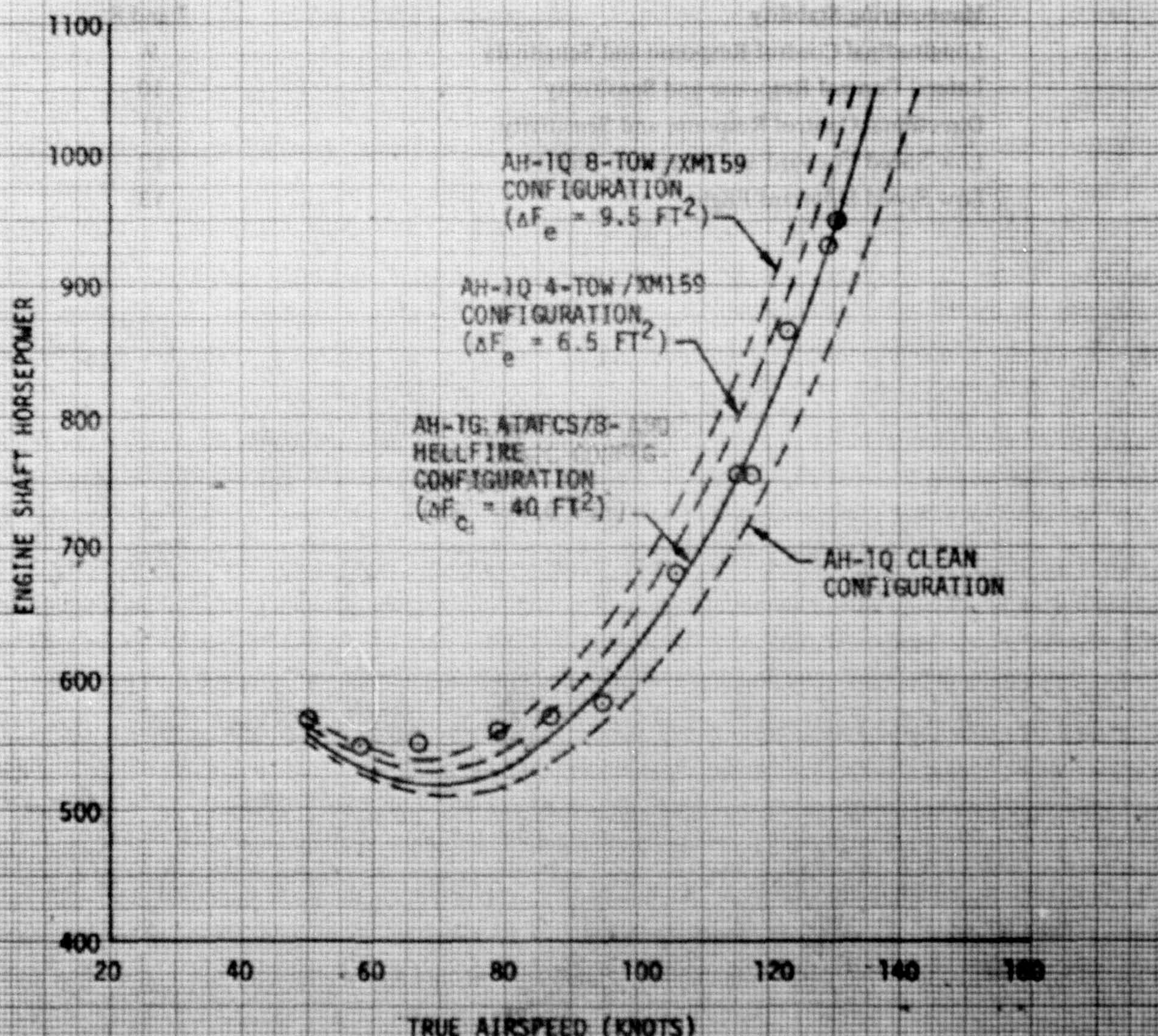


FIGURE 2

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

AH-1S USA S/N 78-16089

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
8800	194.2(FWD)	0.0(MID)	5340	8.0	324	ATAFCS/8-HELLFIRE

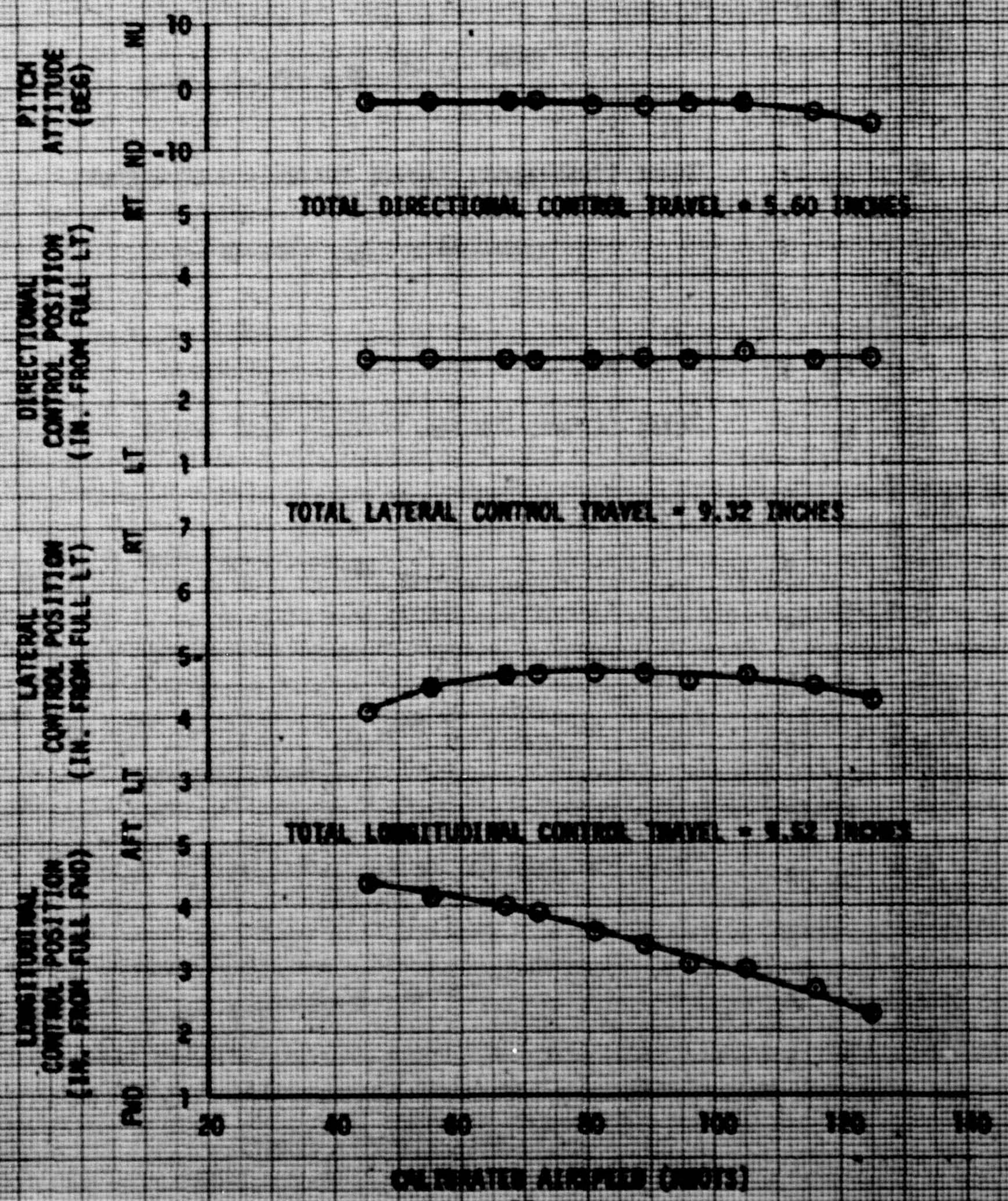


FIGURE 3
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
AH-1G USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	CONFIGURATION
8700	194.3(FWD)	0.0(MID)	5400	8.0	324	LEVEL	ATAFCS/ 8-HELLFIRE

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. SCAS ON
3. CONTROL FORCES OBTAINED USING FIG. 12, APP H, REF 9.

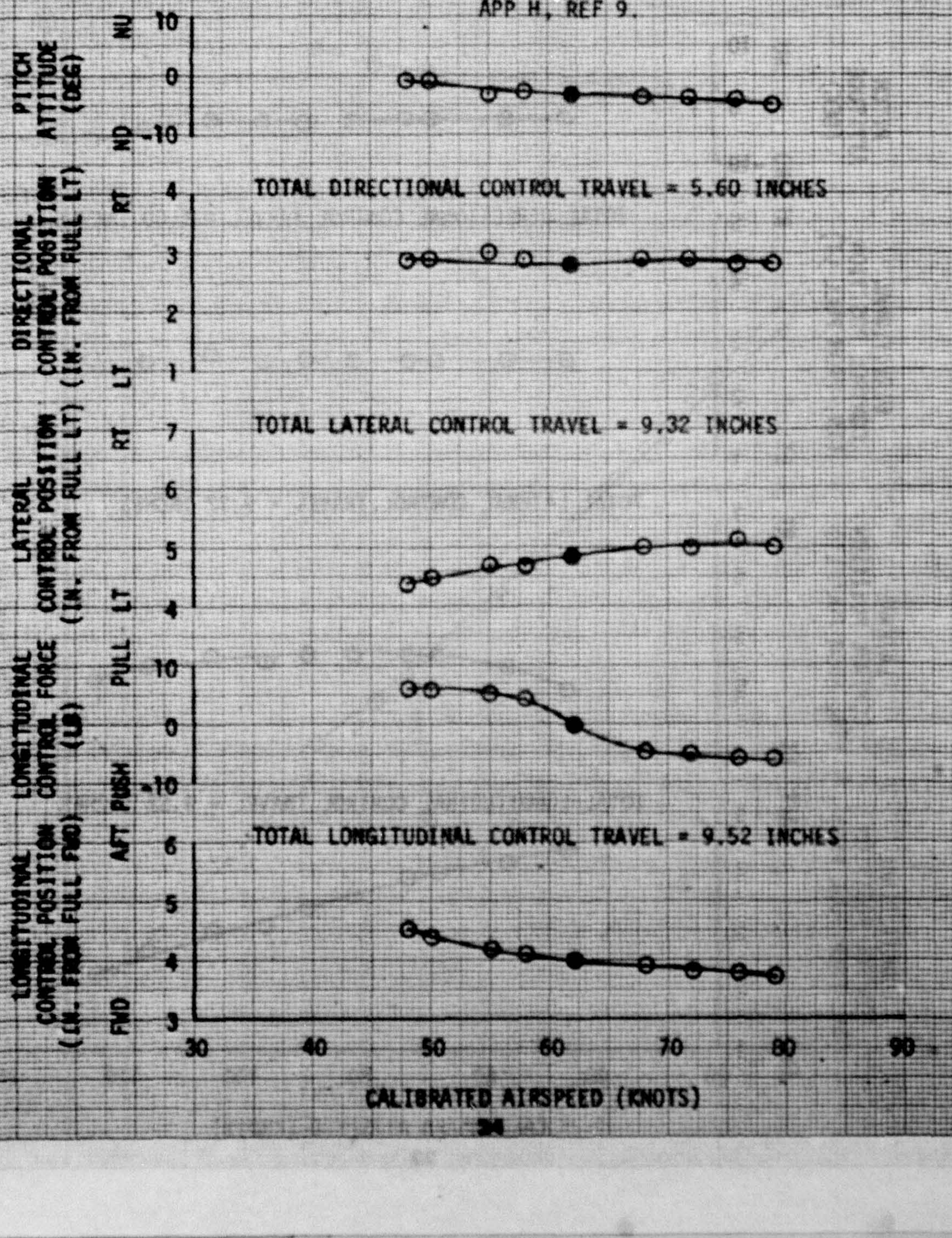


FIGURE 4

COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY

AH-1G USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	CONFIGURATION
8600	194.3(FWD)	0.0(MID)	5200	8.0	324	LEVEL	ATAFCS 8-HELLFIRE

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. SCAS ON
3. CONTROL FORCES OBTAINED USING FIG. 12, APP H, REF 9

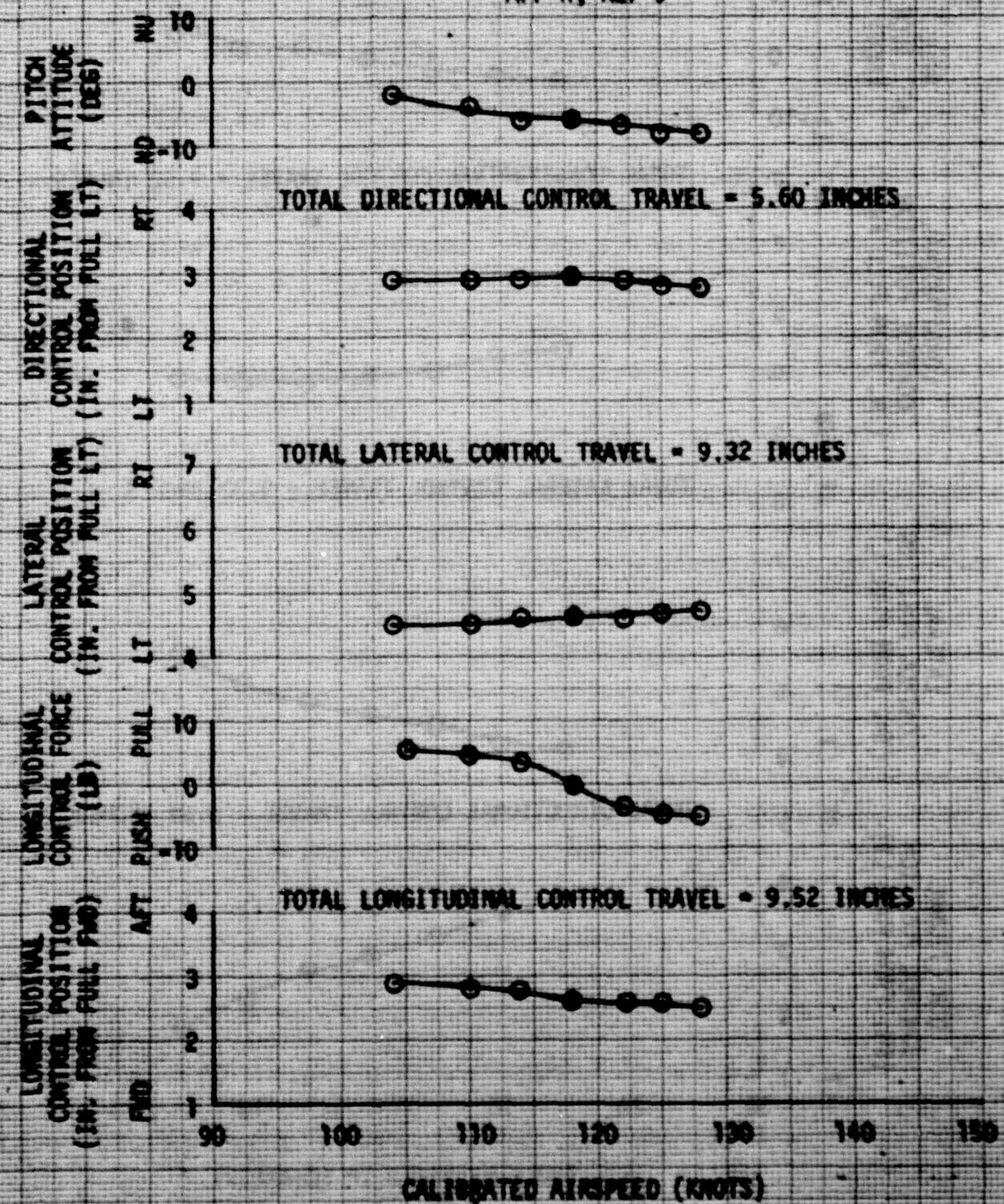


FIGURE 5
STATIC LATERAL-DIRECTIONAL STABILITY
AH-1S USA S/N 76-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	CONFIGURATION
8860	194.3(FWD)	0.0(MID)	4800	9.0	324	63	WINGS 8-HELLFIRE

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. SCAS ON
3. CONTROL FORCES OBTAINED USING FIG. 13, APP H, REF 9

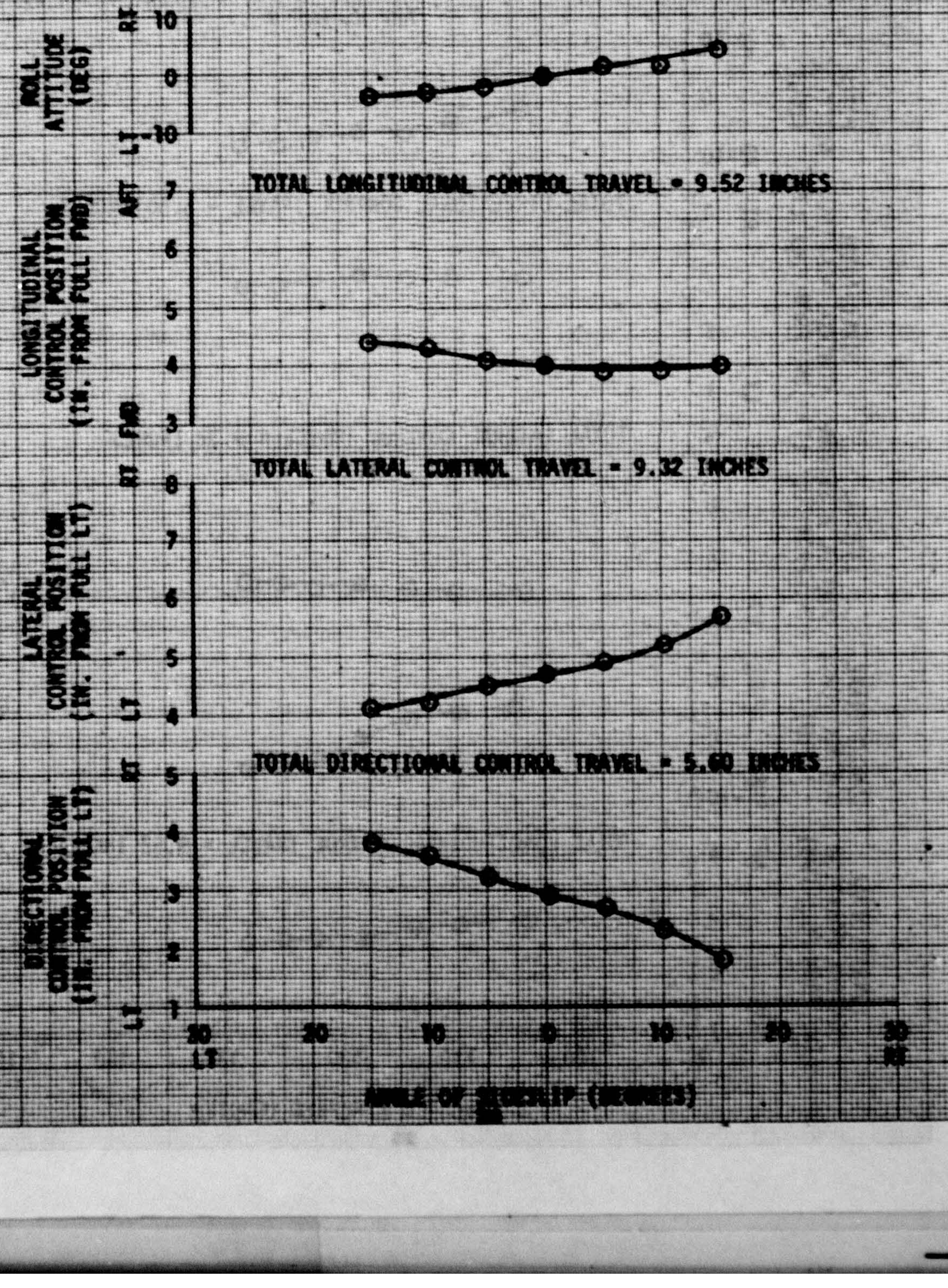
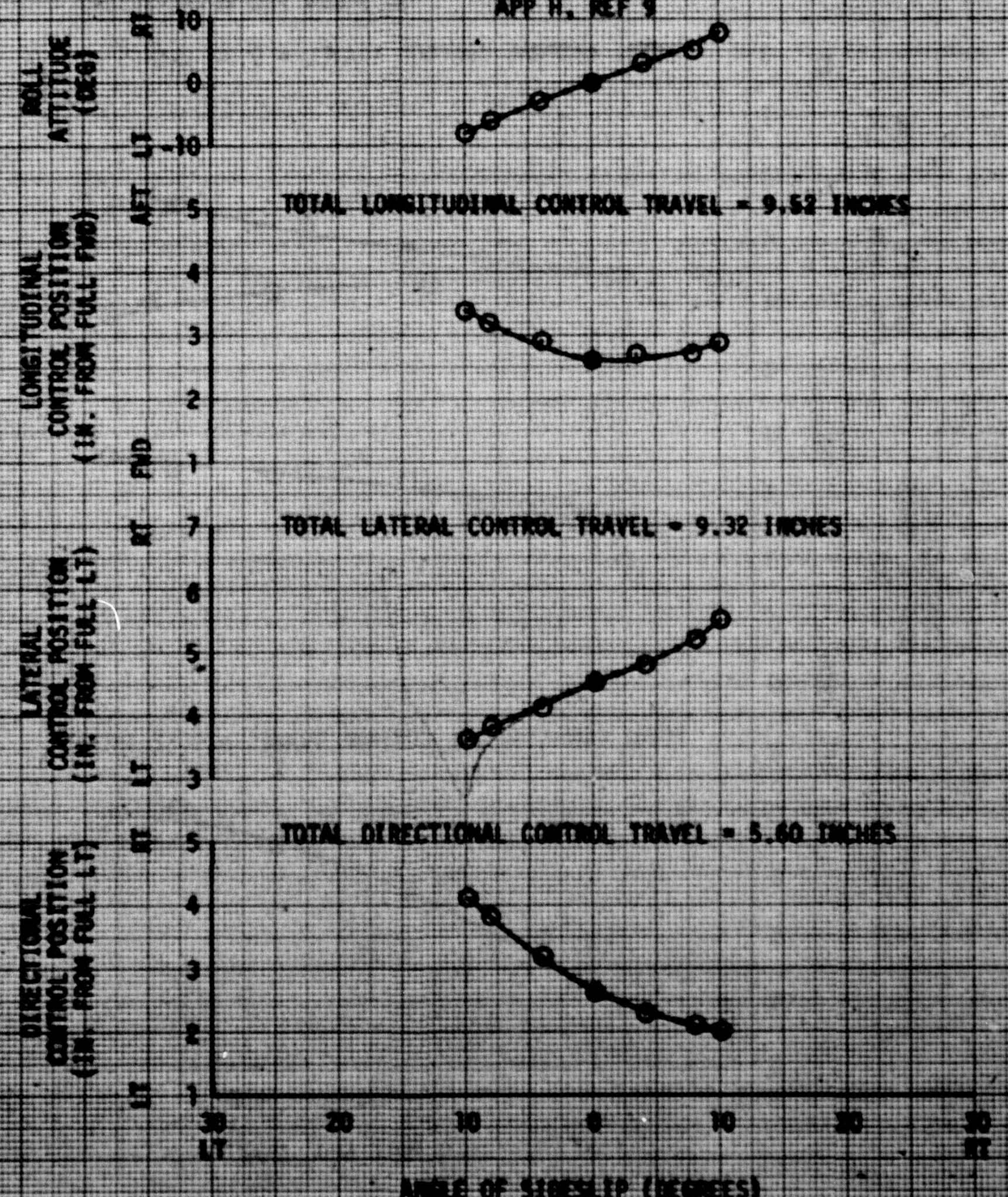


FIGURE 6
STATIC LATERAL-DIRECTIONAL STABILITY
AH-1S USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	CONFIGURATION
[illegible]	194.3(FWD)	0.0(MID)	4600	9.0	324	120	ATAFCS 8-HELLFIRE

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. SCAS ON
3. CONTROL FORCES OBTAINED USING FIG. 13, APP H, REF 9



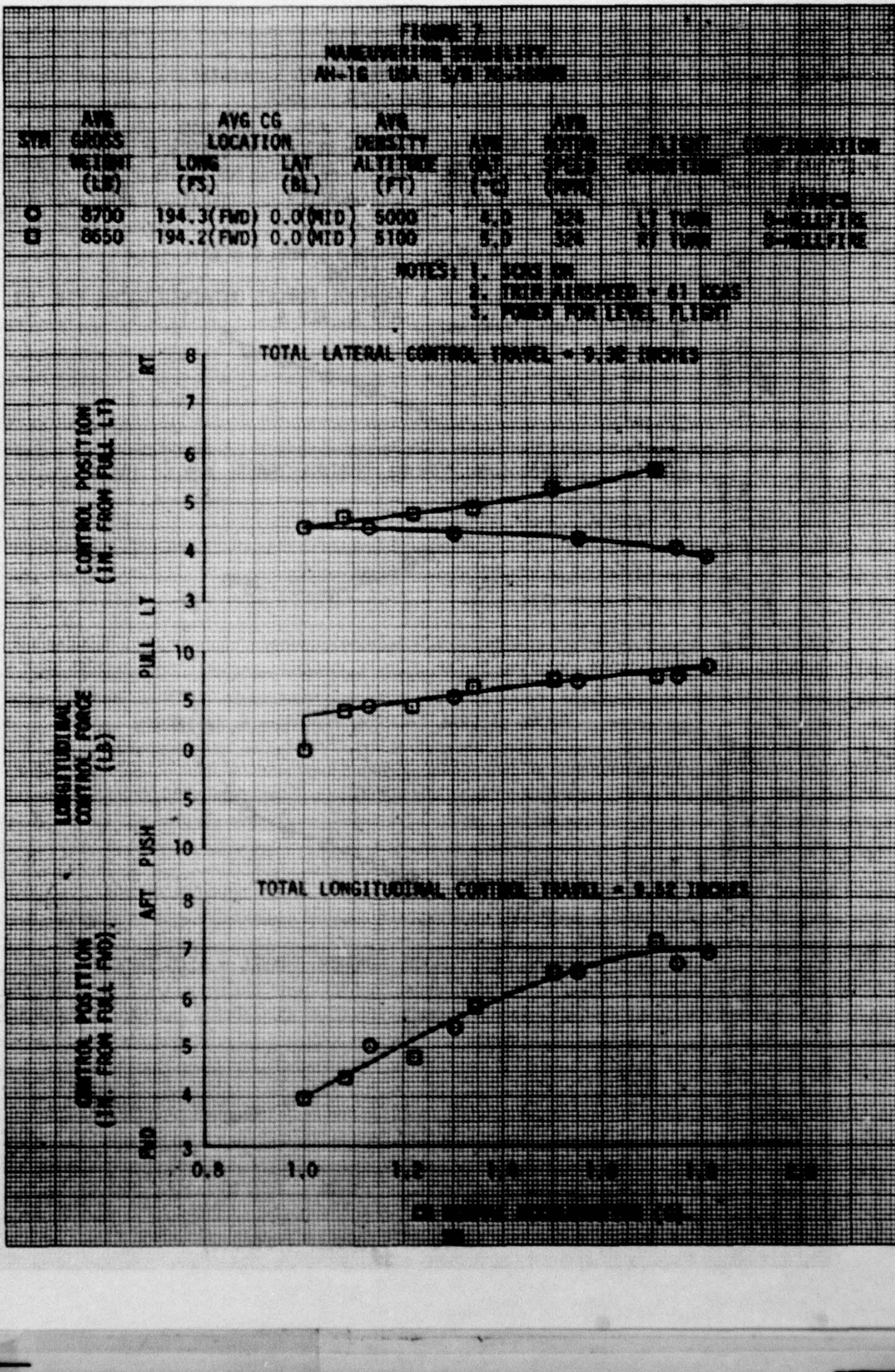


FIGURE 7
MANEUVERING STABILITY
AH-1G USA
SYM
AVG GROSS WEIGHT (LB)
AVG CG LOCATION
LONG (FS)
LAT (BL)
AVG DENSITY ALTITUDE (FT)
AVG OAT (°C)
AVG ROTOR SPEED (RPM)
FLIGHT CONDITION
CONFIGURATION
8700
194.3(FWD)
0.0(MID)
5000
4.0
326
LT TURN
8-HELLFIRE
8650
194.2(FWD)
0.0(MID)
5100
5.0
326
RT TURN
8-HELLFIRE
NOTES: 1. SCAS ON
2. TRIM AIRSPEED = 61 KCAS
3. POWER FOR LEVEL FLIGHT
TOTAL LATERAL CONTROL TRAVEL = 9.30 INCHES
CONTROL POSITION (IN. FROM FULL LT)
RT
LT
LONGITUDINAL CONTROL FORCE (LB)
PULL
PUSH
TOTAL LONGITUDINAL CONTROL TRAVEL = 9.52 INCHES
CONTROL POSITION (IN. FROM FULL FWD)
AFT
FWD
0.8
1.0
1.2

FIGURE 8
MANEUVERING STABILITY
AH-1G USA S/N 70-16069

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION	CONFIGURATION
○	8600	194.2(FWD)	0.0(MID)	5000	5.0	324	LT TURN	ATAFCS 8-HELLFIRE
□	8550	194.2(FWD)	0.0(MID)	4900	5.0	324	RT TURN	8-HELLFIRE

NOTES: 1. SCAS ON
2. TRIM AIRSPEED = 117 KCAS
3. POWER FOR LEVEL FLIGHT

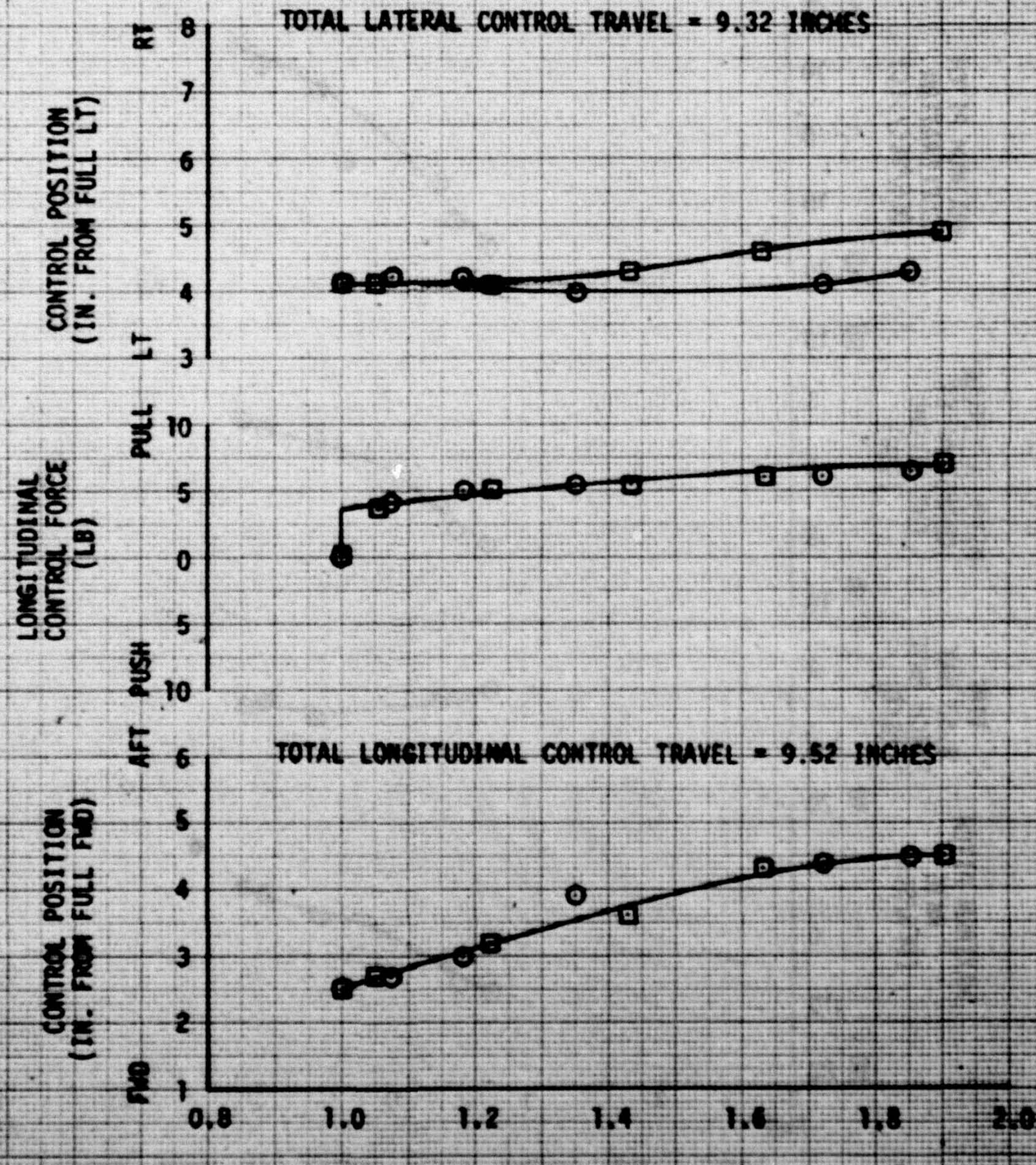


FIGURE 9
LONGITUDINAL CONTROL RESPONSE AND SENSITIVITY
AH-1G USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SKID HEIGHT (FT)	CONFIG.
8600	193.5(FWD)	0.0(MID)	1800	8.0	324	0 (HOVER)	100	ATAFCS

NOTE: SCAS ON

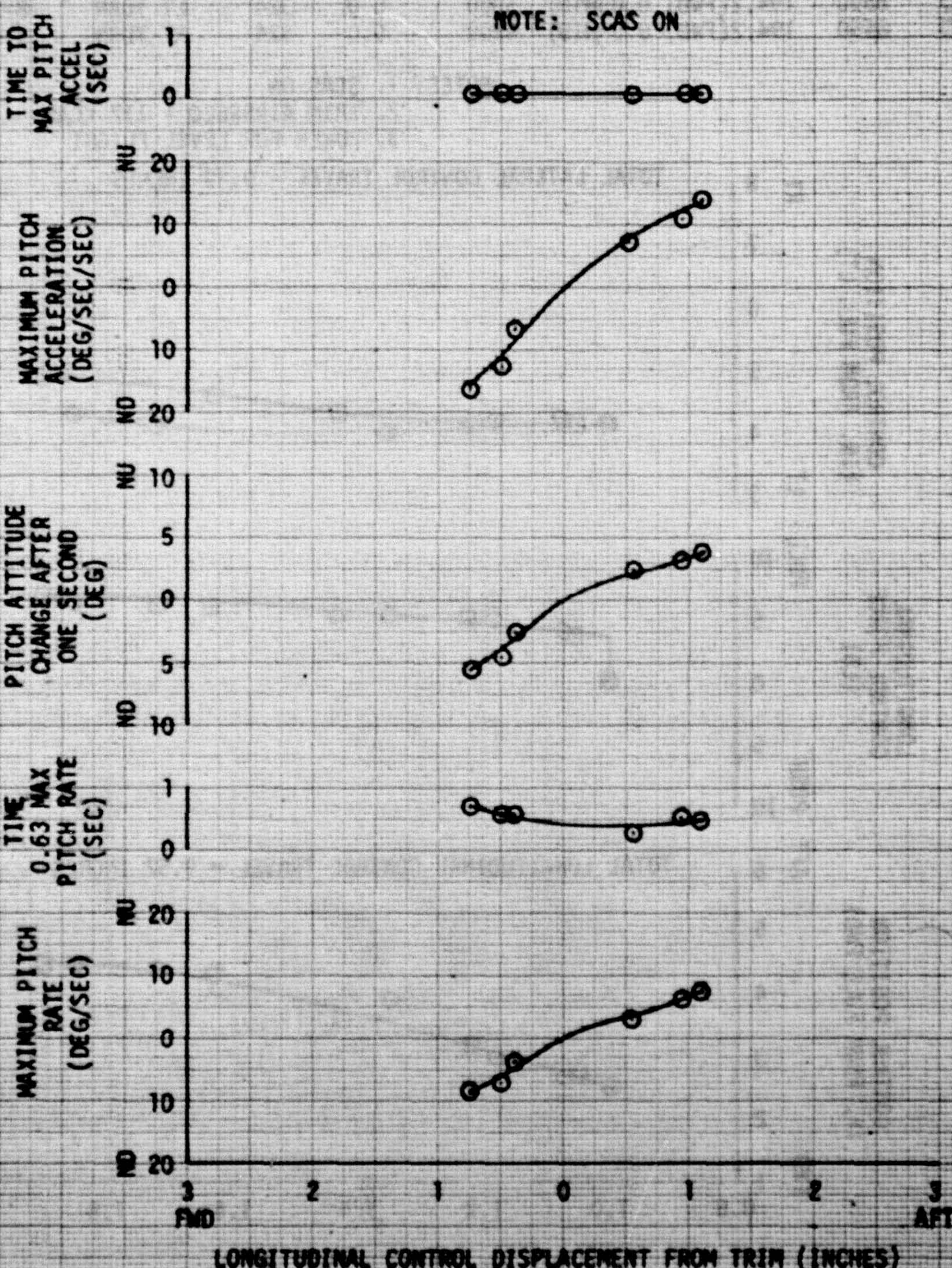


FIGURE 10
LATERAL CONTROL RESPONSE AND SENSITIVITY
AH-1G USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SKID HEIGHT (FT)	CONFIG.
8620	193.5(FWD)	0.0 (MID)	1800	8.0	324	0 (HOVER)	100	ATAFCS

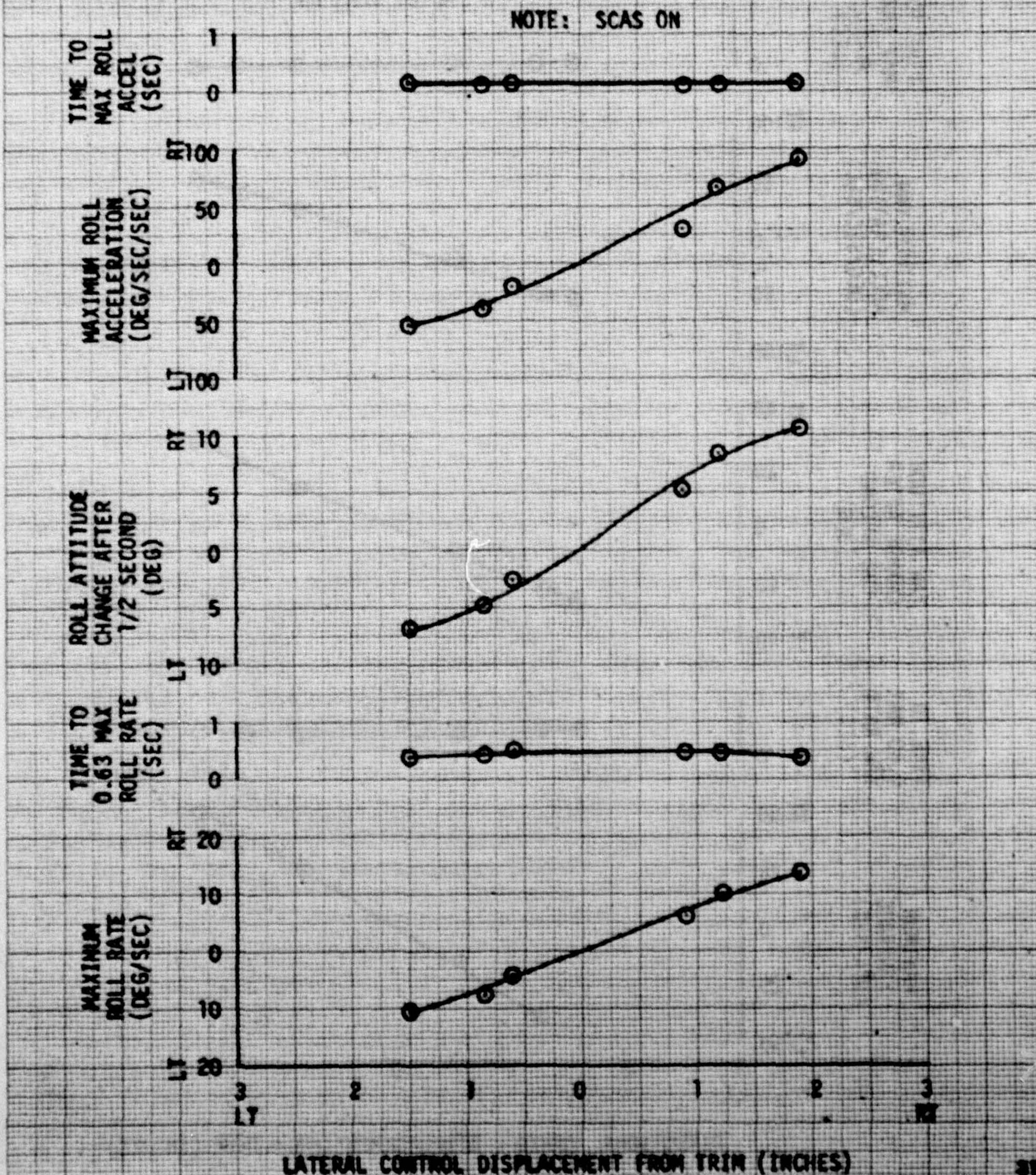


FIGURE 11
DIRECTIONAL CONTROL RESPONSE AND SENSITIVITY
AH-1G USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SKID HEIGHT (FT)	CONFIG.
8640	193.5(FWD)	0.0(MID)	1800	8.0	324	0 (HOVER)	100	[illegible]

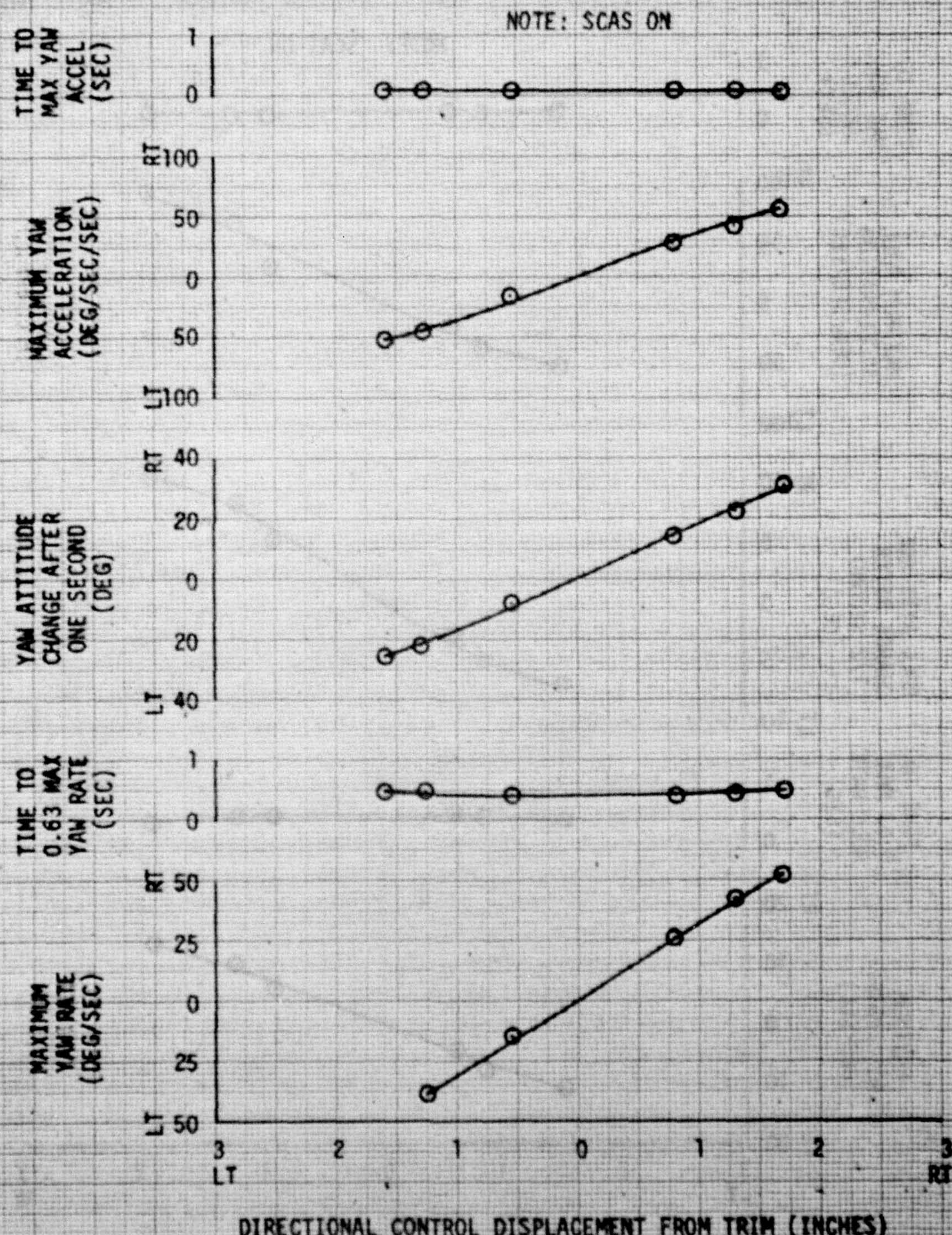


FIGURE 12
LOW-SPEED FORWARD AND REARWARD FLIGHT
AH-1G USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG SKID HEIGHT (FT)	CONFIGURATION
8450	194.3(FWD)	0.0(MID)	1800	9.0	324	10	ATAFCS/ 8-HELLFIRE

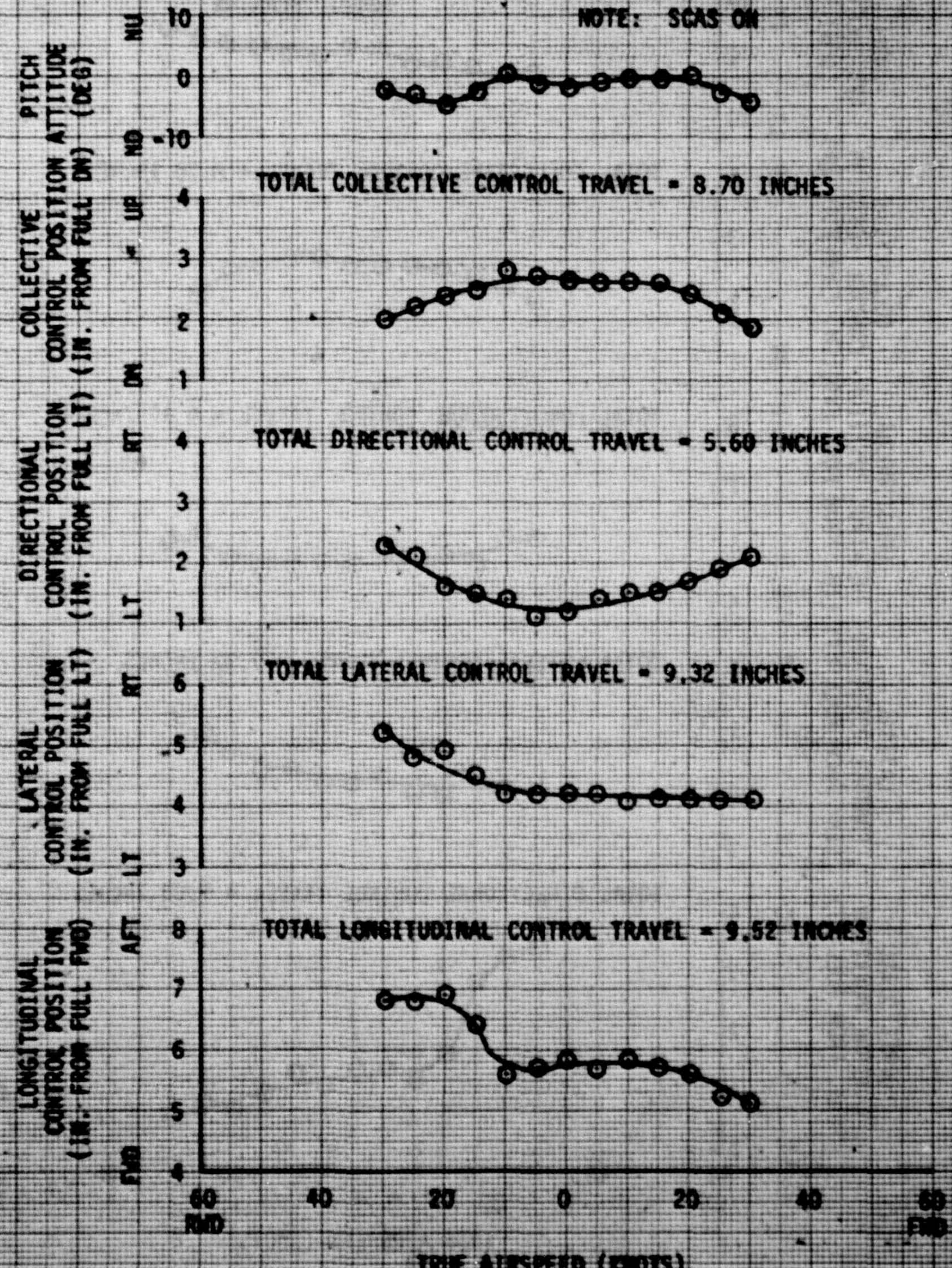
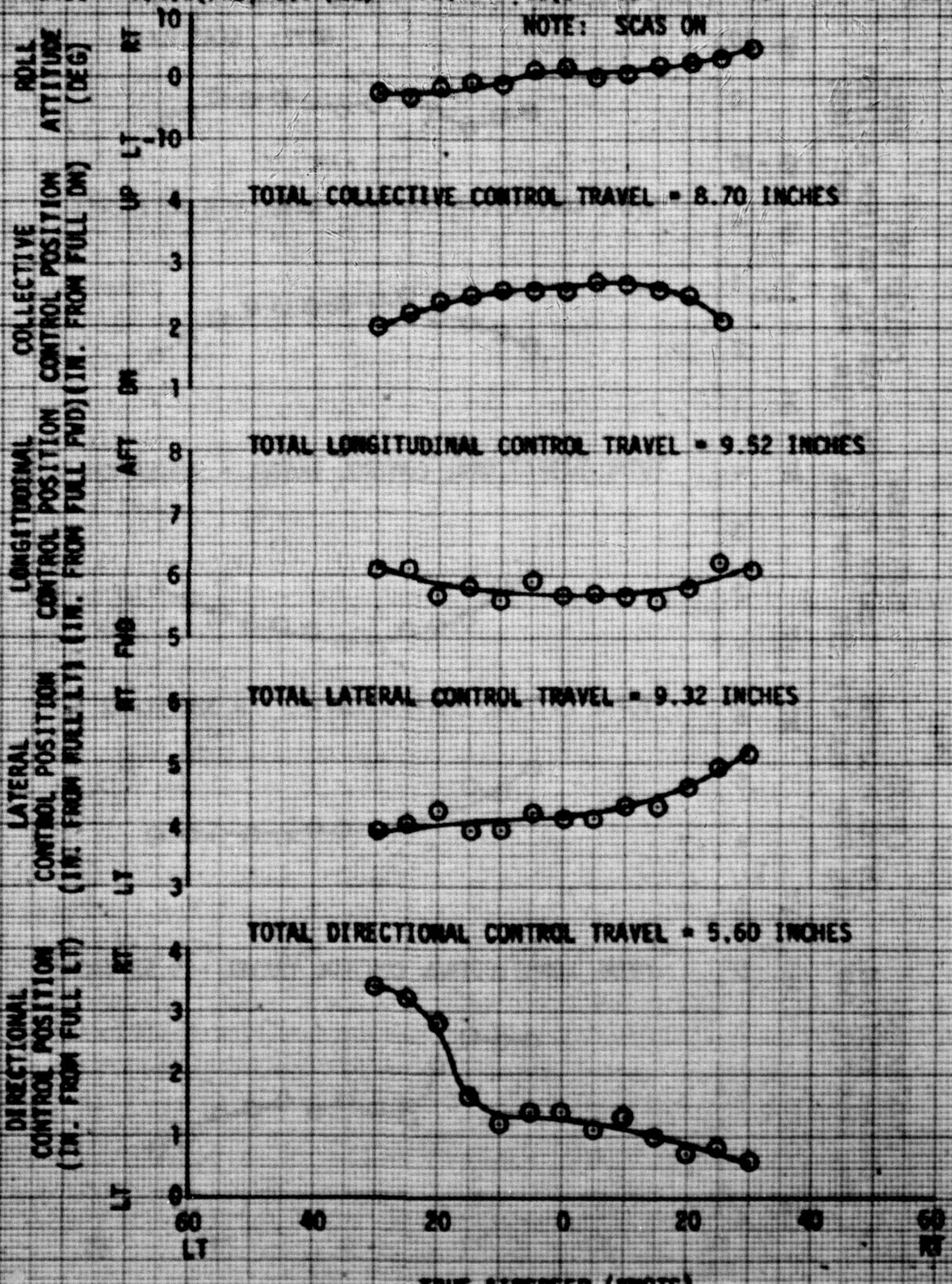


FIGURE 13
SIDEWARD FLIGHT
AH-1G USA S/N 70-16069

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG SKID HEIGHT (FT)	CONFIGURATION
8400	194.3(FWD)	0.0 (MID)	1920	10.0	324	10	ATAFCS/ 8-HELLFIRE



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